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Paper Read at the Tunbridge Wells Hospital, May, 1912.

THE WONDERS OF

RADIUM,

EXPLAINED IN A POPULAR MANNER,

BY

SIR DAVID L. SALOMONS, Bt., M.A.

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SIXPENCE.

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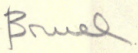

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RADIUM.

This brief discourse is intended to place before you, in a popular manner, the wonders of Radium, which have revolutionised modern Science, and indeed, hold out the promise of giving to mankind new powers, undreamt of a few years ago. It is necessary to omit all calculations, technical data, and various delicate experiments, from which the facts here given were obtained, and many of these facts, moreover, cannot be accepted as perfectly accurate, since it is desired to avoid a considerable amount of technicality which must otherwise be introduced, if the subject is to be treated from a purely scientific standpoint. My object is to explain to the mind which is not technical, the wonders of radio-active matter, and the results possible from the discovery. Consequently, the simplest language and the simplest methods must be employed. I have taken my facts in a large measure from the papers and works of Professors Rutherford, Strutt, Soddy, Makover, Sir William Ramsay, Sir J. J. Thomson, the Curies, Becquerel, and others.

It was Becquerel who first investigated the radio-active nature of Uranium; and later the Curies, when examining Uranium ore for radio-active properties, found some minerals far more active than would have been expected, and naturally concluded that there must be something more in the material than the Uranium they were examining. The result was the discovery of a highly radio-active substance called Polonium, which is in fact a substance produced from Radium during its disintegration. Later, the Curies found the element known as Radium, which Madame Curie was recently able to obtain in a metallic state, but which could not be kept in that state owing to its rapid combination with other elements. In fact, Radium is generally used in the form of a bromide, sulphate, or other combination.

The remarkable property of a radio-active substance is that no matter in what combination it may find itself, its individuality remains exactly the same. This is not so with other elements. For instance, oxygen combined with iron, commonly known under the name of rust, oxygen combined with hydrogen in the form of

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water, or oxygen in the state of gas, furnish examples of how the oxygen, so to speak, hides its identity under different clothing, whereas with Radium, its existence could be at once detected by the greatest novice employing tests of the simplest kind: for instance, its power to render certain substances luminous when looked at in the dark.

In order not to carry the subject over too wide a field, we will limit ourselves to the one substance Radium, which is usually placed in small tubes, or spread with varnish over a small flat surface, or on cloths, when used medically for curative purposes, and is generally a radium bromide. The strength of the compound is expressed by saying so much pure crystalised radium bromide with so much barium, since the Radium works as if bromine, etc., were not present, the radio-activity of the compound depending solely on the quantity of the Radium contained. Also the strength of the salts is expressed by a figure giving its activity compared with uranium, taken as unity. For instance, say the radium salt is given as 200,000; this means 200,000 times more active than uranium. The Radium chloride and bromide are soluble in water, whereas the sulphate and carbonate are insoluble. Consequently salts in the soluble form must be used covered, since moisture, also air and heat, lower the radio-activity.

A radio-active substance is best examined by photographic methods. For instance. a piece of mineral containing any such material may be cut and polished, then placed on a photographic plate contained in a black envelope, and in course of time the plate will be impressed. The time may be a few hours, days or weeks, according to the amount of active material present, but eventually, on developing the plate, the radio-active substance will have produced its impression, and so delicate is the test that one part in a hundred millions, or even a far smaller quantity may be detected. Such detection would be impossible by any chemical or spectroscopic method of testing known at the present time.

Anyone can try the following simple experiment:—A radio-active substance called Thorium, which forms the chief part of the

well-known gas mantle, can be tested photographically by flattening out the mantle upon a photographic plate contained in a black envelope. In the course of a few hours, on developing the plate, it will bear the impression of the mantle, due to the radio-active action of Thorium.

Radium and other radio-active substances may be regarded as Creation unfinished, the progress of which we can watch.

When Radium was first discovered, the wildest statements were made, one being that its properties could remain active for millions of years, but it is now ascertained that about 2,500 years is the limit. Radio-activity is an indication that the material atoms are disintegrating, or in common language, decomposing into new bodies, or in the formula of the old alchymists, it is the transmutation of the elements.

I may at once point out, without going into details, that it is quite probable that all matter is gradually disintegrating, but the time required to do so for substances which cannot be detected as radio-active is so great as to be practically infinite from the human point of view, and no instruments or methods for detecting such slow disintegration exist at present. Moreover, as far as present knowledge goes, any transmutation will always be of the opposite kind to that which the old alchymists sought, viz., from a heavier substance to a lighter one, and not from a lighter to a heavier one as desired. Consequently, if ever transmutation be possible in regard to gold, it will not be from silver, iron or other cheap metals, since they are lighter than gold, but it will have to be from heavier metals, which at present are more expensive than gold, and therefore would not be worth the game.

Since it would appear that matter disintegrates from a heavier to a lighter one, it is conceivable that a time will arrive, should the world last so long, that only what we call light substances will exist. The notion carried further, leads to a possible time when all matter will have disintegrated into an almost weightless substance or disappear.

The fact that Radium and certain other radio-active substances have been discovered is due to the circumstance that the disintegrating process is, in these instances, exceedingly rapid, and the complete transformation from one element to another or others, is brought about in a time which can be appreciated by humanity.

Since Radium is estimated to exist for 2,500 years, the question naturally arises: How is it that Radium is found in the world at the present time, since we have no doubt as to the world being older than that period of years? The only answer that can be given is, that Radium must be forming all the time to make good its disappearance, and since it is only found in minerals containing Uranium, it is natural to conclude that Uranium, which as I have mentioned is radio-active, is changing into Radium, though, of course, it may go through many stages before it becomes Radium, and indeed, this fact may be accepted as proved. It is true that Radium is found in minute quantities elsewhere, but this is probably due to the same causes which have produced the universal distribution of other elements by the action of rivers and seas over geological times, also to volcanic dust.

From remarks already made, it will appear evident that since the Uranium deposits in the earth are scarce, as far as is known at present, the production of Radium must be limited, and indeed as time goes on, must become less and less, owing to the disintegrating process, i.e., Uranium, the father of Radium, will become less in the world, since it disintegrates into Radium and other substances, and finally, Radium is destined to disappear. Uranium is two million times less radio-active than Radium. Consequently, it can be shown by reasoning, as well as by experiment, that its complete disintegration must take two or more million times longer than Radium. In fact, it is calculated that Uranium can only exist 7,500,000,000 years, and Radium, as already mentioned, only 2,500 years.

There has long been a dispute between physicists and geologists as to the age of the world, the former giving the world a

comparatively few million years, whereas the geologists demand a vastly longer period for the crust of the earth to appear as it is. The discovery of Radium has supplied the missing link, and reconciled the opposing camps. It also assists astronomers to explain the great difficulty which has always pursued them in accounting for the gigantic energy which we see nightly displayed in the stellar systems. It may also explain the source of heat of the sun, and a number of other phenomena which, according to the older view, were given a duration far too short to satisfy scientific requirements.

The energy contained in Radium is so great that an ounce of it would do the work of 150 tons of coal, but to obtain the result in a given time, a condition is necessary which at present is unknown to man, viz., that this energy shall be delivered up, not in 2,500 years, but in a much shorter and more practical period. This is a problem for the future which is not limited to Radium. Probably all matter contains an almost unlimited supply of concealed energy, and when the discovery how to release this energy is made, it will revolutionise mankind, for we live entirely by energy and nothing else.

It is impossible to theorise as to what might happen when the discovery comes about. It may come to-morrow, or it may never, as far as mankind is concerned, but if it comes, all present politics, social problems, and other conditions which we regard as essential for our well being, must inevitably be completely revolutionised. Property, as such, could no longer exist, for energy, which is now only obtained with great difficulty, backed by capital, will then be available with little or no effort, and open to all. However, it is useless to speculate about a future which may never come. It is better to take what we have and know, and consider our subject Radium as we find it.

Radium gives out certain rays which are named alpha, beta, gamma; also a so-called emanation, as well as heat and light. Likewise, effects are produced similar to the X-ray effects due to the

beta rays. It produces in certain substances phosphorescence or fluorescence, it renders air and gases a conductor of electricity by what is termed ionizing them, and it also produces a variety of physiological effects. Likewise various chemical effects are produced, and many crystaline stones are changed in colour and made to sparkle, i.e., alter their refractive and dispersive powers. Besides possessing all these properties, Radium renders radio-active many substances which are exposed to its rays, and the activity lasts a longer or shorter time according to the nature of the substance. Its atoms decompose, or more strictly speaking, disintegrate into a variety of other substances, and the final disintegration, it is believed, is into lead, since in Uranium ore, lead is always found with rare exceptions, and even when not present, explanations can be given for its absence.

The first transformation of Radium is to give off alpha rays, which consist of the gas helium charged with positive electricity. Helium is twice the weight of hydrogen, which is the lightest matter known. The gas helium had already been discovered in air. The emanation, a kind of gas, is far more radio-active than the Radium itself, and it is this emanation contained in the Radium which gives most of the effects. The emanation disintegrates into what is termed Radium A, this again into Radium B, again into Radium C, again into Radium D, again into Radium E, again into Radium F. This Radium F was the one first discovered by Madame Curie, to which she gave the name Polonium, in honour of her native country. And so on the process continues till what is believed to be the final disintegration, lead, and possibly, lead again may disintegrate, but only over a period so long, and so slowly, that we cannot now measure the change. It is remarkable to observe that in producing these Radiums A, B, C, D, etc., their lives vary considerably. In many cases it is but a few days, in others it is years, and there appears to be no connecting law as to how long these elements keep their individualities. Most of these various transformations give out rays like the parent radium, some of only one kind, others more. The

designations Radium A, B, etc., are employed in order not to create confusion by giving each a separate name. It must be borne in mind that the Uranium is not changed direct to Radium, but passes through many transformations before reaching that element.

The alpha rays travel at the enormous speed of 8,000 to 12,000 miles per second. They traverse the air a short distance, and suddenly their travel is arrested. It is not a case of a railway train pulling up gradually. They proceed at their maximum pace and suddenly stop. A thin layer of metal, thick paper or glass will stop their progress. In other words, if a thin sheet of metal or paper or glass be held over Radium, the alpha rays will be partially or entirely stopped, according to the thickness of the screening material, but the beta and gamma rays pass on. The beta rays are believed to consist of electricity separated from matter, and they are all electrically negative. Their speed is enormously greater than that of the alpha rays. The beta rays travel at about 10C times the velocity of the alpha, and the gamma travel about 100 times faster than the beta. Lead is found to be the most opaque to all the rays. If a metal sheet—aluminium or lead is usually employed—is made beyond a certain thickness, the beta rays are cut off, and the gamma rays alone proceed through the metal. The gamma rays travel at practically the same speed as light, not less than 180,000 miles per second, light travelling at 185,000 miles per second. These gamma rays pass through lead even to the thickness of four inches, and apparently like light, are ether waves.

It is found that a large number of the phenomena which are produced by radium arise from the alpha rays, and as we have seen that it requires very little to stop the alpha rays, and very little more to stop the beta rays, it is therefore a comparatively simple matter to select either of these rays for medical treatment, but the gamma rays may be taken to be always present, and whether they have any considerable action compared with the others is not easy to say.

The simplest way to detect the presence of Radium is under the X-ray screen in the dark, when it will render it luminous, or to put it over a piece of willemite, which is a zinc mineral, or over a zinc blend screen, when they will fluoresce.

A little instrument designed by Sir William Crookes, called by him spintharoscope, shows the alpha ray particles visually. It consists of a needle with a trace of Radium on the point, held over a small zinc blend screen, and a magnifying glass above for viewing. To observe the phenomenon, it is necessary to be in the dark for a minute or two, then look at the screen through the lens. There will be seen what appear to be shooting stars. These are the alpha particles hitting the screen. They are, of course, given off in all directions from the point, but those which are shot against the screen become visible to the eye. This apparatus helps to bring to mind what a remarkable substance Radium must be, and how extraordinarily delicate is the test. In fact, the eye becomes the instrument of the test. These needles can be made radio-active by the hundred, and the amount of Radium required on the hundreds is practically nil. All that is necessary is to have a little glass tube in which Radium had been contained, a tube no larger in diameter than a cedar wood lead pencil, and no longer than one inch. To make these needles, the points have merely to touch the side of this empty tube, in order to become sufficiently radio-active to produce the desired effect, moreover, these shooting stars will continue, whether you are looking at them or not, for considerably over 2,000 years. The only thing that wears out is the screen which is being battered by these particles. It is not the infinitesimal quantity of Radium which is wearing itself to death, but the screen which is worn out in about two years by the incessant bombardment of these alpha particles!

The great difficulty which scientists had to deal with, when radio-active substances were discovered, was to reconcile the new order of things with the old, for up to that period some 12 or 13

years ago, the atom was regarded as the smallest portion of matter which could exist, and was indivisible.

Dalton, who founded the atomic theory, applied his theory with success, and it has been accepted ever since. Then we come suddenly to the discovery that radio-activity is due to the disintegration of the atom itself, which we had hitherto relied upon as indivisible, and this discovery, like an earthquake, appeared to destroy all that had been built up in the past on the atomic theory, because we find that the "indivisible atom" is capable of breaking up again into particles which can only be counted by the billion. Fortunately, the old order of things can still hold its own, so that chemists, physicists, and others need not go to school again, for it happens there is a point where the two theories can be reconciled, but we must be prepared any day for some extraordinary new discoveries after what we have seen in recent years. The idea of radio-activity thirty years ago would have been ridiculed, i.e., that the elements could be further broken up and the construction of the atom further analysed. Yet it has been done, and we are in a state of daily expectation of further discoveries, rather than settling down with an idea of finality as to the composition of matter.

Newton could only account for the light reaching the earth from the sun by propounding the theory that minute particles of matter are projected from the sun, and eventually reached the earth. This theory ultimately gave way to what is known as the undulatory theory, but after two centuries the theory suggested by Newton is found to be true in the case of radio-active matter.

One grain of Radium bromide, if pure, contains a hundred million billion atoms of radium, and throws off every second about 2,000,000,000 alpha particles.

Radio-active analysis has now been carried to such a fine point that no process known in the most up-to-date laboratory of a few years ago would be of the slightest use for measurement. Spectrum-analysis is far more delicate than any balance or chemical

method, and will detect say one in a million, and there is the end of it, but when it comes to the methods now employed for the detection of radio-activity, one in five hundred millions is a very simple matter, and for one in a billion, no difficulty exists.

The process by which disintegration takes place can only be compared to a series of violent explosions. Why they take place is not explained. It is due to some want of stability, but to say this does not explain the reason why. Knowing the gigantic energy stored up in matter does not explain how that energy got there, and these are mysteries which may perhaps never be solved, or may be solved by pure accident before mankind has disappeared from the earth.

In order to better illustrate how remarkable is this discovery of radio-activity, and how entirely it revolutionises all previous ideas, I will give the following facts, which may be taken as approximately correct:—

It has been estimated that the amount of Radium believed to exist in the earth, assuming the crust of the earth is 50 miles thick, would be sufficient to account for the heat which continually escapes from the earth into space, but it must not be assumed from this statement that the heat is due to this cause alone.

Since alpha rays are particles of matter, viz., helium, and their velocity is about 500 times faster than any speed of material previously known, viz., that of the shooting star which is from 20 to 40 miles per second, that mass for mass, their kinetic energy is 250,000 times greater than anything ever known before.

If we could obtain a pint of the emanation, and half a ton of pure Radium would be required for this purpose, it would radiate the energy of 100 powerful arc lamps. Indeed, no vessel could contain this pint of gas, because all known substances would be vapourised by the heat.

The energy evolved by Radium changing is about a million times greater than that evolved from any equivalent amount of

known matter. One grain of Radium produces no less than 125,000,000 calories (heat units), whereas one grain of coal yields, when burnt, only 500 calaries. One ton of Radium would give the energy of about 250,000 tons of coal when burnt (for coal when burnt does not yield but a fraction of its calories).

The heat given by Radium may also be expressed in another way by saying that the heat expelled by a grain of radium per second would raise the same weight of water from freezing to boiling point in the same time.

Fourteen ounces of uranium oxide, worth about £1, could be put into a small bottle, and in itself is contained energy equal to at least 150 tons of coal. It has been estimated that if it were possible to make the uranium give up its energy within twelve months, that one ton of it would light London for a year, but unfortunately a method of making uranium yield up its energy in a given time has not, and may never be discovered. Uranium contains 14 times more energy than Radium, weight for weight.

When Radium bromide is dissolved in water, the emanation is given off,, and as already mentioned this emanation is highly radio-active. Then the dissolved residue, when dried, is found to be very slightly so, but the sum of the two radio-activities is found to be equal to that of the Radium before it was dissolved. In about thirty days the emanation will have disintegrated into other products, and lost the greater part of its radio-activity, whereas in proportion as the emanation loses its activity, the Radium residue gains, and at the end of the 30 to 60 days it is found to be as radio-active as it was before being dissolved, having re-made fresh emanation. This explains why freshly made Radium has to be kept, or as it is termed "aged" before it reaches its maximum activity, since it went through a dissolving process in the last stage of manufacture. Also to prevent the emanation from escaping, the salts must be kept in closed tubes, or protected in some other manner. When it is desired to ionize water, an insoluble salt, such as

Radium-sulphate is put in the water. In due course the water takes up the emanation.

If a tube containing Radium is held between the fingers for a few seconds, or longer, the sensation of "pins and needles" will be produced. (This experiment should only be performed at long intervals to avoid regrettable results). Now to the novice, this may appear very remarkable, and scientifically it is. But I would recall a simple experiment which has been performed by everyone, quite as remarkable, but the magic word Radium does not enter, so it passes unnoticed. When we touch a piece of iron made very hot, but not hot enough to show redness, it produces pain and burns the skin. Had the fact just been discovered, certainly mankind would have been startled. The action of the Radium is akin to the hot iron, though of another order. I mention these facts to show that there is nothing extraordinary in producing physiological effects from cold as well as hot bodies, if suitable for the purpose.

It may also be of interest to state that in order to obtain Radium from Uranium ore, generally known by the name of pitch-blend, it is necessary to treat one ton of this ore with about 50 tons of water and five to six tons of various chemicals, and every ton of a good class ore yields not more than from five to six grains of Radium. It is this laborious process which takes a very long period of time, and a great deal of skill, particularly during the final stages of the operations, which makes the cost of the Radium so great.

I would also point out that the fact that Radium frequently cures cancer, and various other affections of an allied nature, and that it also produces effects somewhat resembling cancer, has suggested the prevalent idea that here again is an instance of "like curing like," but it is not so in this case at any rate. It is believed that Radium does not produce pure cancer, although it produces sores which at present are found difficult, if not impossible to cure. It is generally thought that the action of Radium produces some chemical alteration in the cells of the tissues, and in the one case

enables the cells to regain a healthy course, while in the other case it turns the healthy into the unhealthy state. It is remarkable that the X-rays, as is well known, also produce a species of cancer or ulcer which appears almost incurable, but by using Radium on such sores they heal.

The present cost of Radium is so great, owing to its scarcity, and the enormous difficulty attending its production from the uranium ore, that the value of pure crystalised Radium bromide possessing radio-active properties at least one to two million times greater than uranium, which is taken as the standard of unity, works out at from £16 to £21 per milligramme. Putting this into more general language, one grain is worth about £1,400. Radium being one of the heaviest substances known, it can be realised how small a volume a grain would occupy, and one can understand how Radium may be described as money compressed into a very small compass. Also, the temptation to the thief is not great, for the possession of Radium by uninitiated persons may mean death to them.

In conclusion, wonderful as all these discoveries are, there is one yet to be sought for, and this one may never come within the grasp of man, though no scientific man would be so bold as to predict the impossibility, after seeing the extraordinary things which have come to light in recent years. I refer to what may be termed the "Essence of Life." Such a discovery would probably be scouted by religious people. Yet when other great discoveries were made in the past, they were denied, ridiculed, and banned by pious people; to-day they are accepted, and religion still remains. There is nothing wrong, nothing against religion, in wresting from Nature her store of secrets. On the contrary, the greater the wonders we find, the more we are awed by the marvels of Creation. We know that all living organisms are built up from inorganic matter, but there is something which converts the inorganic material into living matter. It is clearly not the "soul," for plants are at present denied this advantage. Evidently, if we could solve the "Essence of Life" for plants, we should have the key to the

animal kingdom also. It is merely to find a way to manufacture one living cell, since complicated living organisms are built up of cells. I believe the day will come when the secret will be found, though as with all discoveries, a great element of chance exists, but the discovery of radio-activity may be the stepping stone. Should this time ever arrive, the expectation that disease may some day be eliminated, will be near fulfilment, for the method to build up healthy cells in the place of the unhealthy, will be within our power, and we shall not then be experimenting with drugs without knowing precisely how they act, for we judge their results only by experience.

It may well be said that the study of Science stands foremost; it enables man to appreciate the wonders of Nature, and to feel more reverence for the Superior Power, by realising how little he can get behind the hidden secret of the Why and Wherefore of all that we see around us.

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